3.1.1 Kinematics

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	displacement, instantaneous speed, average speed, velocity and acceleration	*M0.1, M1.4, M3.7, M3.9* HSW10, 12
(b)	graphical representations of displacement, speed, velocity and acceleration	*M3.6* HSW3 Using data-loggers to analyse motion.
(c)	Displacement–time graphs; velocity is gradient	*M3.4, M3.7*
(d)	Velocity–time graphs; acceleration is gradient; displacement is area under graph.	Learners will also be expected to estimate the area under non-linear graphs. *M3.5, M4.3*

(6) M - Define and calculate acceleration
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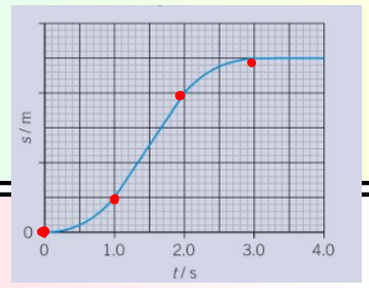
Lesson 2: Acceleration and velocity time graphs

0:00:00

STARTER:

Describe and **explain** how the velocity of this object changes over 4 seconds



HWK (due next lesson):

Kilo 10^3 Split your graph into clear sections..

Mega 10^6 What could this object be?

Giga 10^9 Use calculated values for velocity in your answer

Self assess

Key point

/12

www:
ebi:

1. 0-1s velocity increases because **gradient** increases.
2. 1-2s velocity is **constant** because **gradient** is constant
3. 2-3 velocity decreases because gradient decreases.
4. 3-4s stationary because gradient = zero

WWW/EBI

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Acceleration of selected events (smallest to largest)

a (m/s^2)	event
5×10^{-14}	smallest acceleration in a scientific experiment
2×10^{-10}	galactic acceleration at the sun
9×10^{-10}	anomalous acceleration of pioneer spacecraft
0.5	elevator, hydraulic
0.63	free fall acceleration on pluto
1	elevator, cable
1.6	free fall acceleration on the moon
8.8	International Space Station
3.7	free fall acceleration on mars
9.8	free fall acceleration on earth
10–40	manned rocket at launch
20	space shuttle, peak
24.8	free fall acceleration on jupiter
20–50	roller coaster
80	limit of sustained human tolerance
0–150	human training centrifuge
100–200	ejection seat
270	free fall acceleration on the sun
600	airbags automatically deploy
10^4–10^6	medical centrifuge
10^6	bullet in the barrel of a gun
10^6	free fall acceleration on a white dwarf star
10^{12}	free fall acceleration on a neutron star

Acceleration and the human body

a (g)	event
2.9	sneeze
3.5	cough
3.6	crowd jostle
4.1	slap on back
8.1	hop off step
10.1	plop down in chair
60	chest acceleration during car crash at 48 km/h with airbag
70–100	crash that killed Diana, Princess of Wales, 1997
150–200	head acceleration limit during bicycle crash with helmet

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Acceleration

Per unit time.


Key point

Acceleration is the rate of change of velocity with time

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

ms^{-2}

$$a = \frac{\Delta v}{\Delta t} \ (ms^{-1}) \ (s)$$

$$a = \frac{v - u}{t}$$

Kilo 10^3

Mega 10^6

Giga 10^9

1. A distressed car is rolling backward, downhill at 3.0 m/s when its driver finally manages to get the engine started. What velocity will the car have 6.0 s later if it can accelerate at 3.0 m/s^2?

2. During a typical accident, a properly designed bicycle helmet should keep acceleration of the head below 200 g for a cumulative duration of three milliseconds and 150 g for a cumulative duration of six milliseconds. At what speed did the authors of this standard assume a typical accident would take place?

3. What car 'zero-to-sixty' time is equivalent to an average acceleration of 1 g?

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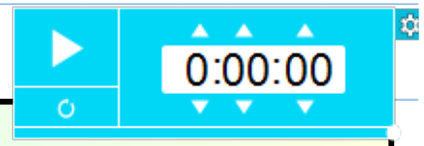
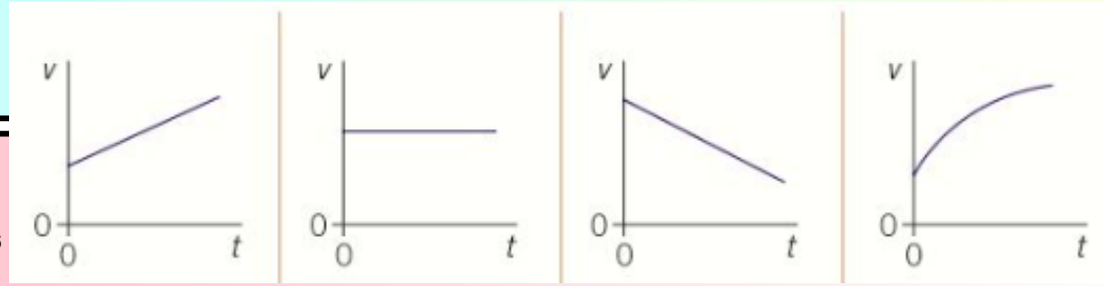
Velocity time graphs



ACTIVITY:
Discuss - Describe the **gradient** and then the **velocity** and **acceleration**



Kilo 10^3
Mega 10^6
Giga 10^9

What could these object be?

gradient. increasing zero decreasing.
velocity increasing constant increasing
acceleration constant zero. constant (-ve) decreasing.

Key point

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ACTIVITY:

Sketch the velocity time graphs of the following:

- A ball falling through air into water then continuing to fall.
- A ball thrown up in the air and falling down again.
- A golf ball dropped onto a hard surface and bouncing 3 times

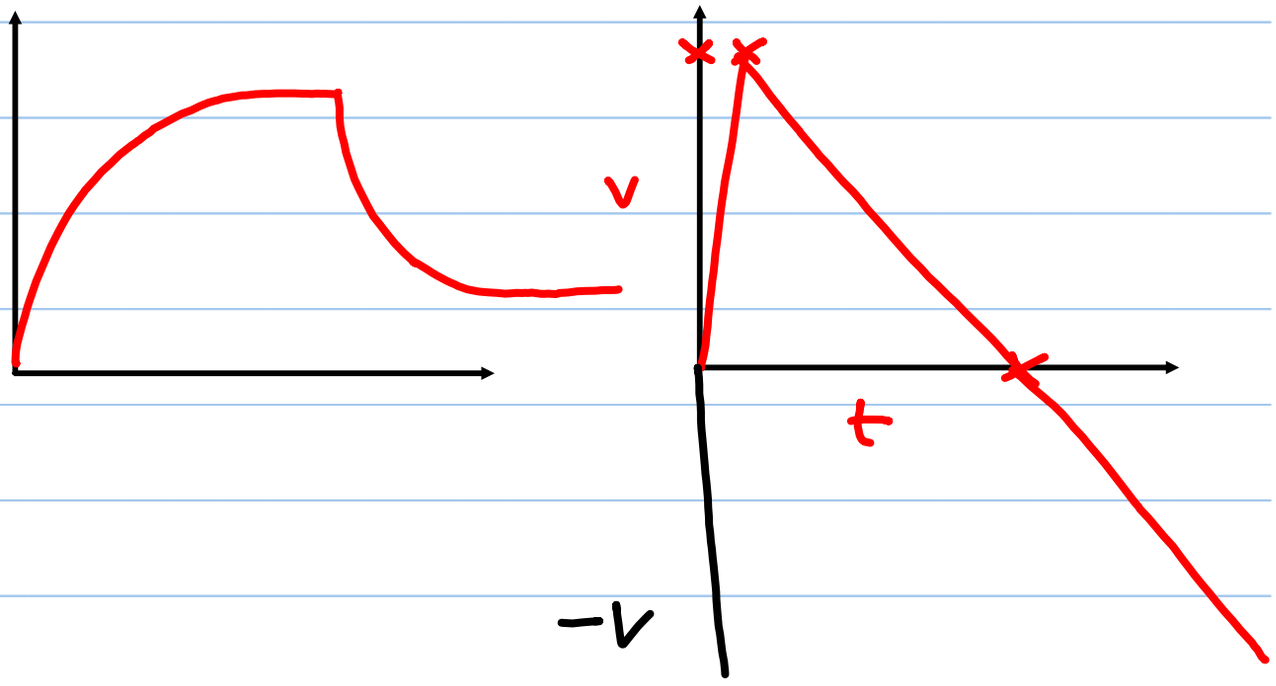
Kilo 10^3

Mega 10^6

Giga 10^9

A snooker ball rebounding off of a cushion

Key point



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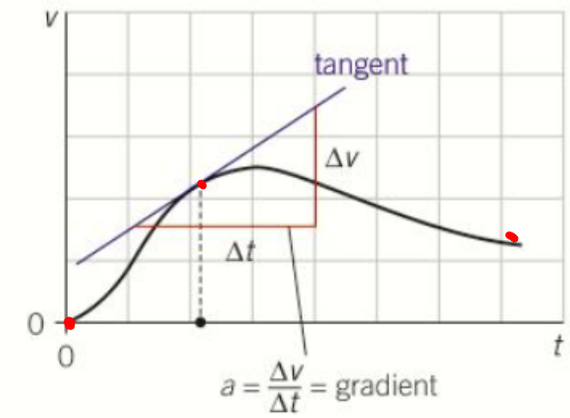
Analysing velocity time graphs

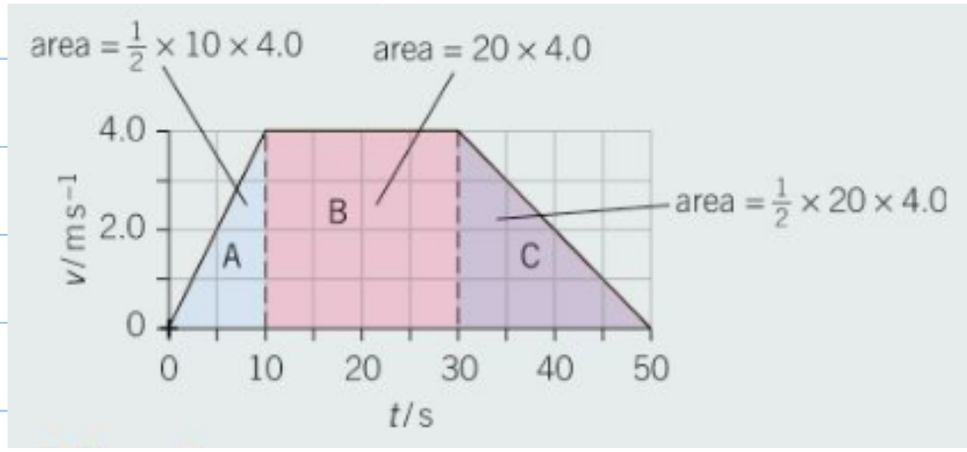
What information can be gained from a v-t graph?

Key point

The **gradient** of a velocity time graph is equal to the **acceleration**



The **area under** a velocity time graph is equal to the **distance** travelled.



Complete the worksheet on velocity time graphs

(6) M - Define and calculate acceleration
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ACTIVITY:

Complete the worksheet on velocity time graphs

Kilo 10^3

Mega 10^6 What could this object be?

Giga 10^9 Use calculated values for velocity in your answer

Key point

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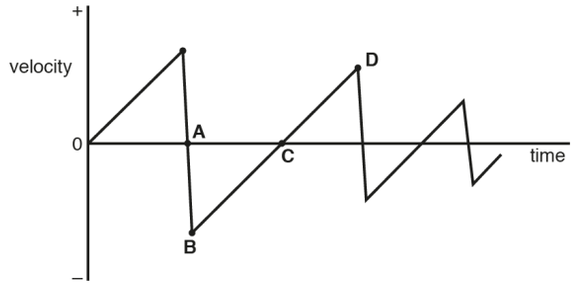
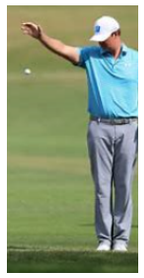
Mini plenary

A golf ball is dropped from rest onto a hard floor.
The graph shows how the velocity of the ball varies with time as it bounces, from the time of release.

At which point does the ball reach its maximum height after the first bounce?





Mini plenary

Which row gives two features of graphs that provide the same information?

	Feature 1	Feature 2	
A	Gradient of a displacement–time graph	Area under a velocity–time graph	⬭
B	Gradient of a displacement–time graph	Area under an acceleration–time graph	⬭
C	Gradient of a velocity–time graph	Area under a displacement–time graph	⬭
D	Gradient of a velocity–time graph	Area under an acceleration–time graph	⬭

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plenary

Compare displacment time graphs with velocity time graphs

	displacement time graphs	velocity time graphs
y-intercept represents..		
Gradient of tangent		
Positive gradient		
Negative gradient		
Zero gradient		
Straight		
Curved		
Area under curve		
when 2 lines coincide...		
Object is stopped when...		
constant acceleration looks like..		

	displacement–time	**velocity–time**
"*y*" intercept	initial displacement	initial velocity
slope of tangent	instantaneous velocity	instantaneous acceleration
positive slope	motion in positive direction	acceleration in positive direction
negative slope	motion in negative direction	acceleration in negative direction
zero slope	not moving	not accelerating
straight	constant velocity	constant acceleration
curved	changing velocity	changing acceleration
area under curve	–	[change in] displacement
curves coincide	objects have same displacement	objects have same velocity
stopped when…	horizontal	crosses *t*-axis
uniform acceleration	parabolic	straight

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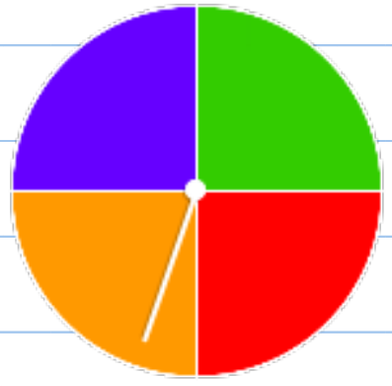
plenary

Area under a V-t graph

Equation for velocity

Equation for acceleration

Definition of velocity



Definition of Acceleration

Gradient of a S-t graph

V-t graph: Ball thrown up then falling back

Gradient of a V-t graph